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# Naturalistic study on the usage of smartphone applications among Finnish drivers

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ABSTRACT

We present results from a naturalistic study that tracked how Finnish drivers use their smartphones while on the move. We monitored 30 heavy in-car smartphone users in Finland during June–September 2016, recording the times that they used their phones, the application used at the time of touch (calls excluded), the location and driving speed. Touches per time unit were used as a proxy for estimating visual-manual distraction due to visual-manual tasks. Our data set allows the determining of whether drivers use their phones differently on varying road types (highway, main road, local rural road, urban road). We found that the road type has an effect on phone use but the effect is contrary to what we expected. Drivers produced more touches per hour on urban roads, yet the use instances tend to be shorter than on the highway or main roads. We also collected statistics on the applications that were used. By far the highest overall rankings in the number of drivers using, number of uses, and duration per use instance was associated with the WhatsApp messaging service. One instance of WhatsApp use had a median of 8 touches, and had a median duration of 35 s. In contrast, navigation application use included a median of 3 touches and lasted for 11 s. The findings suggest that the Finnish smartphone heavy-users do not decrease their phone use when the demands of the traffic conditions increase and that the greatest risk from smartphone use may be currently caused by messaging applications.

## 1. Introduction

Driver distraction by mobile phone use has been associated with increased safety-critical incident risk in traffic (e.g. Klauer et al., 2006; Victor et al., 2015). In many countries traffic law regulates the use of smartphones (and other mobile devices) while driving. For instance, in Finland all disruptive use of and the hand-held use of communication devices while driving is forbidden by Finnish traffic law (24.5.2022/423, 24 a §). The law allows the use of a smartphone by the driver only if the phone is equipped with a hands-free system (e.g. a car holder). Despite these regulations, recent polls have revealed the majority of Finnish drivers admit to using their smartphones frequently. Furthermore, even 25% of them admit to using smartphones for messaging while driving (Jääskeläinen and Pöysti, 2014).

Although it is well known that many drivers use their smartphones to do various tasks while driving (e.g. Klauer et al., 2006; Victor et al., 2015; Jääskeläinen and Pöysti, 2014), little to nothing is known about the actual applications they use or the exact traffic conditions in which they use those applications. This information is important for determining the actual risk level caused by the phone use. A given application use, such as texting, may cause a very serious risk of accident on busy and congested urban roads. The risk may be considerably smaller when driving along a straight and nearly empty highway.

There is evidence from naturalistic driving (e.g. Wierwille, 1993), as well as from on-road (e.g. Wikman et al., 1998) and simulator studies (e.g. Metz et al., 2011), suggesting that drivers adapt their off-road glancing behaviours according to the dynamic demands of the driving task. Drivers tend to decrease their off-road glance durations and the number of off-road glances when the demands of the driving task increase. The naturalistic field study of Metz et al. (2013) on maneuvering (German drivers) and the video-clip based study of Hancox et al. (2013) also suggest that drivers tend to attend to distracting activities in a situationally-aware manner.

In this paper, we present findings from naturalistic driving data that enabled us to determine what applications drivers use, for how long and how much, and whether they use applications differently in different driving scenarios. Although there is no exact way to determine the visual-manual distraction caused by any given application, we used the number of touches per time unit on the smartphone as a proxy. A touch on a touch screen is almost always accompanied by a glance on the touch screen due to the limited haptic feedback of the device (Burnett and Porter, 2001; Salvucci and Kujala, 2016).

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Salvucci and Kujala (2016) show behavioural protocol data of glancing behaviours towards a touch screen while driving (based on data by Kujala and Salvucci, 2015). In all of their identified visual sampling protocols, a touch on a touchscreen device was always accompanied by a glance. Infrequent smartphone interactions may be accomplished via touch without the need for visual guidance, such as a simple scrolling gesture (although scrolling often necessitates visual guidance as well). However, typical smartphone screen sizes and touch screen interactive elements are small, and precision is needed to guide the finger towards the desired position. This applies to writing with a touch screen keyboard, in particular. Yet, even if we assume that every touch was associated with a glance, that does not mean that the glance durations are comparable. Accepting a call might be easy to do with a brief glance, whereas text entry using a small keyboard requires more precision and many sequential key presses, and hence, longer glances. Also, some tasks might require visual attention without many (or any) touches (e.g. reading text vs. text entry). A limitation of our touch data is that it does not tell us if the drivers modulate their smartphone glance durations based on the demands of the road environment. However, we argue that touches per time unit serve as an indicator of the level of visual-manual activity with the smartphone. Thus, touches per time unit can be (indirectly) associated with the potential of visual-manual distraction from the driving task.

Among others, Victor et al. (2015) have suggested that a series of glances away from the road in a short period of time may lead to safety-critical uncertainty of the task-relevant road events, even if the glances off road are brief. Therefore, an application that causes a large number of touches in a short time period can be considered to cause high uncertainty of the driving-related events for the driver. On the other hand, an instance of use, of which duration is long, means that the driver may be distracted for a longer period of time. Longer in-car tasks have been associated with increased probability of increased individual glance durations off road (Kujala and Salvucci, 2015; Lee et al., 2012).

Based on the previous research findings, our preliminary hypothesis was that at least experienced drivers should have developed a sense of acceptable risk levels, and would be able to adapt their smartphone usage to the demands of the given driving conditions. We would thus expect to see differences in smartphone usage between road types. In particular, we hypothesized that there would be fewer touches on the phone per time unit and the applications would be less used in high-demand driving scenarios. It was our expectation that urban roads would present the need for the most vigilance due to intersections, traffic lights and other traffic (including cars, bicycles and pedestrians), and hence we would see less phone use in urban conditions than on highway or main roads, even though the highways and main roads have higher nominal speed limits. In order to analyse if different levels of visual-manual activity can be associated with different smartphone applications, we studied the most used applications on the road as well as the number of touches and the durations of application use instances.

## 2. Materials and methods

### 2.1. Hardware and software

The results presented here are a subset of a larger experiment that studied the effects of distraction warnings on smartphone use while driving. The presented data are solely from the control part of the experiments, when phone usage data was collected without any interventions. The control phase was finished by September 2016, but the experimental phase continued until December 2016, ending in a web questionnaire (self-reported car and phone data presented here).

The data gathering system comprised of the driver's personal smartphone and a separate dash-mounted smartphone that communicated with one another. Each time the driver touched their phone the system recorded the time, the application that was used, the vehicle location via GPS, and a picture of the road ahead.

**Fig. 1.** The position of the dashboard smartphone with the Watcher application in a participant's car.

The data were collected using custom software developed by Ficonic Solutions Ltd, located in Jyväskylä, Finland. The software consisted of two parts: a "Watcher" application running on Samsung XCover 3 smartphones that were installed in the volunteers' cars dashboards with a double-suction cup windshield car holder (see Fig. 1), and a small "Observer" application that was installed on all Android phones and other Android devices which the drivers reported to use while driving. The Watcher application created a Wi-Fi hotspot, onto which the Observer phones connected when within range.

The Watcher phones had a continuous cellular network connection to allow enhanced GPS positioning. Data were uploaded to the remote server via 3G or 4G connection, depending on the connectivity in the area, whenever the Watcher application was on standby. The Watcher application recorded the GPS position at one-second intervals whenever the car was in motion. The in-built power-savings system in the Android version meant that whenever the car was stationary, no GPS positions were recorded.

In order to enable the location-based warnings in the second phase of the experiment, the Watcher application constantly mapped the position of the car against the Finnish national Digiroad map data set (http://www.liikennevirasto.fi/web/en/open-data/digiroad), and determined the road on which the car was for any given GPS fix. The application also collected acceleration data on three axes but this data is not analysed in this paper.

The Observer background application in the drivers' Android devices worked by creating a transparent layer over the other applications. A touch on the phone was thus recorded by the Observer application. A flag about every touch was immediately sent over the Wi-Fi network to the Watcher phone, including information about the Android front application (FrontApp) that was running during the moment that the touch took place. The Watcher application took a photo with the back camera of the Android phone by each touch on the driver's phone. The camera was positioned and secured to the windshield holder and dashboard in order for it to have clear visibility of the road environment in front of the vehicle (see Fig. 1).

The car models used by the participants during the study are listed in Table 1 and their Android devices with the Observer application in Table 2 (based on self-reporting). One participant could have up to three cars and three Android devices in use during the research. If the car was changed in the middle of the study, the research equipment was moved to the new car. Most of the participants' cars were equipped with manual transmission (29/40, 72.5%).

### 2.2. Participants

The number of volunteers recruited in the study via convenience sampling was initially 31, starting in June 2016. One participant dropped out of the study before sufficient control data could be collected. The total number of drivers in this study was therefore $N = 30$